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Executive Summary

The United States maintains a National Defense Stockpile (NDS) of strategic and critical non-fuel materials. By law, the Department of Defense (DOD) is required to submit periodic reports to Congress stating which materials, and in what amounts, the stockpile should contain. The Risk Assessment and Mitigation Framework for Strategic Materials (RAMF-SM) is a suite of mathematical models and databases that has been used to support the analyses underlying the stockpile reports to Congress.

A major part of RAMF-SM involves the computation of material shortfalls in the context of a national emergency scenario, which is posited to occur some years in the future. The purpose of this paper is to describe, in considerable detail, the methodology of the material supply adjustment process that forms a part of that computation.

The determination of material shortfalls is modeled by estimating material demands and available material supplies under conditions of a national emergency, and comparing the demand with the supply. Acknowledging the imprecision of all forecasts, the objective remains to make these estimates as accurate as possible, and to consider all pertinent factors.

One such factor is the economic equilibrium principle that under peacetime conditions, up until a national emergency begins, the material supply the United States uses will be essentially equal to U.S. material demand. The raw data on material demand and supply are not guaranteed to be in accord with this principle, in part, because the demand data and supply data are generated by separate sources using different methodologies. The material supply adjustment procedure provides a method for reconciling these data sets and generating adjusted supply values that take into account the equilibrium principle. Applying the procedure can reduce the possibility of "artificial" material shortfalls and surpluses that are mere artifacts of the data development process. This means the shortfalls that RAMF-SM computes are more likely to represent the actual effect of supply and demand disturbances due to the national emergency—and thus provide a more realistic basis for National Defense Stockpile planning.

Contents

A. Function of National Defense Stockpile

The United States maintains a National Defense Stockpile (NDS) of strategic and critical non-fuel materials. The NDS was established during the World War II era and has been managed by the Department of Defense (DOD) since 1988. By law, DOD is required to submit periodic reports to Congress stating which materials, and in what amounts, the stockpile should contain. The most recent such report as of this writing is the Strategic and Critical Materials 2015 Report on Stockpile Requirements (U.S. Department of Defense, 2015), hereafter referred to as the 2015 Requirements Report. The material requirements specified in a Report to Congress are developed in the context of a specific DOD-generated national emergency planning scenario known as the Base Case.

The Risk Assessment and Mitigation Framework for Strategic Materials (RAMF-SM) is a suite of mathematical models and databases used to support the analyses underlying the stockpile Reports to Congress. RAMF-SM, which was developed by the Institute for Defense Analyses (IDA) and is discussed more fully in IDA Paper P-5190 (Thomason, et al., 2015), has six major steps:

1. Identify (and select for study) materials of concern to the U.S. national security community
2. Compute material shortfalls, to assess whether significant problems could result in a planning scenario (applicable to the Base Case, but the methodology also can be applied to other scenarios) in meeting critical demands for materials with supplies likely to be available to the United States
3. Assess the importance of overcoming those shortfalls (or the risks to the United States of not doing so) by deliberate government mitigation actions
4. Identify promising government mitigation options to address any important shortfalls
5. Assess and compare the specific costs and mitigation effects of these government mitigation options, both individually and together
6. Identify priorities among the materials for investments of taxpayer dollars, whether through stockpiling or other government investments, to mitigate potential shortfalls

Step 2 of RAMF-SM is concerned with determining shortfalls of materials in a specified planning scenario, typically a national emergency. Its first three substeps, as defined below, are key:

- Substep 2a determines the U.S. demands for goods and services, and the corresponding demand for output from U.S. industry, that would occur in a certain specified national emergency. These demands are developed via economic modeling, with adjustments to reflect the specific characteristics of the national emergency scenario.

- Substep 2b determines the demands for materials, i.e., the material amounts that U.S. industry needs to produce output that will satisfy the demands computed in Substep 2a.
- Substep 2c determines the available supply of materials, taking into account the characteristics of the particular national emergency scenario examined. It then compares those supplies with the material demands from Substep 2b and computes material shortfalls.[1]

Several mathematical models and dozens of databases, encompassing thousands of data items, support the computations of these substeps. The purpose of the current paper is to explain, in some detail, the material supply adjustment process, which can be regarded as operating between Substeps 2b and 2c of RAMF-SM, as part of the preparation of inputs for Substep 2c. Most of the computations are performed "by hand" (on spreadsheets), rather than via formal analytical models.

B. Background and Rationale

The material supply adjustment process was developed to address issues pertaining to the modeling of material supply and demand, and the development of data for these quantities. These issues include the distinction between production and capacity, the decrement and delay factors, and the methodology differences between supply and demand forecasting. They all have the potential to affect the amounts of material shortfall that RAMF-SM computes. One particular concern is "artificial" shortfalls or surpluses that arise merely because of characteristics of the data development process and do not reflect the effects of the national emergency scenario. These issues are discussed in the sections that follow.

1. Supply Capacity vs. Production

Throughout RAMF-SM Step 2, a distinction is made between a country's *capacity* to produce materials and the amount it actually produces. The capacity is fairly stable over time, but the amount produced can vary considerably and can be indicative of economic factors. In a national emergency scenario, it is reasonable to suppose that the United States can pay producers for production at full capacity, if necessary—and indeed this has been a key assumption underlying the supply and demand analysis.

Throughout the 2005 Requirements Report study, it was assumed that producers' full capacity was *immediately* available to be drawn on. But eventually, it was realized that this assumption might overstate the available supply. The kind of emergency scenario envisioned begins suddenly, with an intense period of conflict, possibly including reduction or shutoff of

[1] Additional substeps of Step 2 include Substep 2d, which models market responses to material shortfalls, and Substep 2e, which determines the appropriate form in which to stockpile a material.

supply from adversary countries. When this occurs, producers in friendly countries would most likely be producing at peacetime levels. It might take some time for them to ramp up to full-capacity production. This ramp-up process is modeled by estimating a peacetime production level for the first year of the scenario (via the Starting Estimated Production, or SEP, methodology, discussed in Section E) and then setting the first year supply somewhere in between estimated production and capacity.[2] (This is done separately for each combination of material and producing country.) The term "supply" is deliberately ambiguous; it might represent estimated production, capacity, or something in between. Section I, on ramp-up, discusses these concepts more fully.

A concern arose, however, that if the production value, as estimated by SEP, was lower than needed, the resulting first year supply value estimate might also be too low, thus creating an "artificial shortfall." Conversely, if the estimated first year supply value was too high, an artificial surplus would result. Therefore, some process was needed to calibrate first year production with peacetime demand, to refine the estimate.

2. SSM Decrement and Delay Factors

The Stockpile Sizing Module (SSM), which is the main computational vehicle used in RAMF-SM Substep 2c,[3] utilizes time-phased (yearly) streams of domestic (U.S.) supply and foreign supply, by country, for each material under consideration. It then applies several sets of decrement and delay factors to the initial foreign supply input values to determine a time-phased stream of available foreign supply. (All the input U.S. supply is considered available.) The total available supply is then compared with demand (in a time-phased manner), and shortfalls, if any, are computed. The decrement and delay factors are input variables for the SSM computer program. They include:

1. reduction or shutoff of supply from adversaries;
2. war damage;
3. decrements to the ability to produce materials;
4. anti-U.S. sentiment;
5. shipping losses; and
6. market share.

The first five of these factors vary by supplier country and are essentially functions of the particulars of the national emergency conflict scenario. Values for them are specified by the Department of Defense and/or the intelligence community. But the market share factor, which

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[2] This intermediate value for first-year supply is the result of an increase in production over the first year as the material producer works its way up to capacity.

[3] The SSM is documented in IDA Paper P-2867 (Santmire, 1997); also see IDA Document D-5270 (Atwell, et al., 2014).

represents the fraction of foreign supply the United States can obtain after the other factors have been applied, is a qualitatively different kind of decrement.[4] The market share concept is applicable in peacetime as well—the United States does not obtain and use all foreign supply of material. The appropriate market share value depends in part on economic factors. It is not unreasonable to adjust the market share to preserve some kind of economic balance—and the supply adjustment process in fact does this.

3. Supply/Demand Data Development Methodology Disparity

A related concern stems from the forecasting of material demand and supply from two different methodologies, which tend to yield disparities between projected demand and projected supply. The material demands are linked to economic demands, i.e., demands for goods and services. Other factors being equal, the economy tends to grow over time, and the economic forecasting models used as part of RAMF-SM (see Section D) tend to project increases in the demand for goods and services over time, which leads to increasing demands for materials.

On the other hand, material supply capacity is usually determined by subject matter experts who know the location of production facilities worldwide, and predict what kinds of capacity (i.e., maximum production capacity) these facilities are likely to have during the scenario period. But they do not explicitly attempt to match the supply capacity to the projected demand. The supply capacity data tend to be "flatlined," with the same value appearing for all years in the future. Given that the demands increase with time, it is conceivable that the demand could exceed the capacity. Even if the capacities are greater than the demand and the initial supply is set to the capacity, the available supply, after the decrement factors are applied, could be less than the demand and result in a shortfall. This indicated shortfall might well be considered artificial, as no attempt was made during the data development to see if supply could be expanded to meet the projected large future demand.

In Requirements Report studies through 2005, the initial supply was set to full capacity. The disparity between supply *capacity* and demand tended not to become large enough to cause artificial shortfalls until a number of years into the future. The workaround was to set the scenario dates only a few years into the future. But when the initial supply is something less than the full capacity, the possibility of an artificially induced shortfall is increased.

4. The Way Ahead: The Material Supply Adjustment Process

The material supply adjustment process in its current form is the end result of trying to deal with all the above factors.

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[4] This is the meaning of "market share" in the context of RAMF-SM Step 2; it is slightly different from the ordinary meaning of the term.

The principle underlying the adjustment process is the economic assumption that, in peacetime, market equilibrium would be maintained until the national emergency scenario of the Base Case begins. Such an equilibrium would imply that under peacetime conditions, the material supply available to the United States would be equal to (i.e., in equilibrium with) the forecasted peacetime U.S. material demand. In particular, the assumption was this would be true in peacetime for the first scenario year.[5]

The supply adjustment process derives a set of U.S. supply, foreign supply, and market share estimates that satisfy this first-year peacetime equilibrium assumption. The process then adjusts these initial peacetime demand and supply amounts to implement assumptions consistent with the wartime scenario of the Base Case, under the guidance of DLA-Strategic Materials. The resultant data are then input to the Stockpile Sizing Module computer program.[6] In short, under the equilibrium peacetime assumption, a material shortfall of zero for the peacetime case (in the first scenario year) is the starting point for building the Requirements Report Base Case. This kind of equilibrium assumption is in accordance with standard economic theory.

A preliminary version of the supply adjustment process was implemented in the 2013 Requirements Report study. The 2015 study used the process documented in this paper.

C. Parts of the Process

The adjustment process has six parts (some of which are often referred to by their acronyms):

1. Computation of Peacetime Demand (Peacetime Demand Method, or PcDM)
2. Starting Estimated Production Methodology (SEP)
3. Peacetime Equilibrium Adjustment Process (PEAP)
4. Maximum Market Share Methodology (MaxMSM)
5. Conflict-related adjustments to maximum market share
6. Ramp-up Process Methodology (RUP)

The process results in data files for U.S. supply, foreign supply, and U.S. market share that are input to the Stockpile Sizing Module.[7] Note that the first four parts of the process pertain to

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[5] In the 2015 Requirements Report study, the scenario ran from 2017 through 2020, so the first scenario year was 2017.

[6] More specifically, the supply adjustment process results in three SSM input files: the U.S. supply file, the foreign supply file, and the market share file. See the next section.

[7] For more explanation of the meaning and structure of these files, see the SSM documentation in IDA Paper P-2867 (Santmire, 1997), or IDA Document D-5270 (Atwell, et al., 2014).

peacetime material supplies and demands, while the last two provide data adjustments to model the conditions of the national emergency scenario.

These parts are discussed in the sections that follow. Except for the first part, the large formal models of RAMF-SM Step 2 are not used to implement the computations. Rather, the computations are performed “by hand” (on spreadsheets). They can be regarded as operating between Substeps 2b and 2c of RAMF-SM, as part of the preparation of inputs for Substep 2c. (Do not confuse the “parts” of the material supply adjustment process with the “steps” and “substeps” of RAMF-SM.)

D. Peacetime Demand Method (PcDM)

The computation of peacetime demand is performed by RAMF-SM Substeps 2a and 2b in a manner similar to the Base Case computation. That is, first the demands for goods and services are estimated over a span of years under peacetime economic assumptions. From these, demand for materials necessary for the United States to produce these goods and services is computed. The Long-term Inter-industry Forecasting Tool (LIFT), Inter-industry Large-scale Integrated and Dynamic Model (ILIAD), and Forces Mobilization Model (FORCEMOB) models used in Substep 2a for the Base Case also can be used in the peacetime case. [8]

The computation of peacetime demand for goods and services is made easier by the economic models (LIFT, followed by ILIAD) whose initial output represents *peacetime* demands for goods and services consistent with the forecast of the Council of Economic Advisers.[9] The subsequent Base Case adjustments to model homeland damage and exclusion of non-essential civilian demand are made to the output of the economic models after they have been run. There is no need to apply Base Case adjustments when computing peacetime demand. Therefore, to examine demands for goods, services, and materials under peacetime conditions, one can simply take the ILIAD output

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[8] Substep 2a utilizes several different large, formal models. Two of these are economic forecasting models from the Inter-industry Forecasting Project at the University of Maryland (INFORUM). They are named LIFT (Long-term Inter-industry Forecasting Tool) (Meade, 2001) and ILIAD (Inter-industry Large-scale Integrated and Dynamic model) (Meade, 2011). Substep 2a also uses a model called FORCEMOB (Forces Mobilization Model) (Schwartz, 1996; also see Atwell, et al., 2015), which applies scenario-specific adjustments to the output of the economic models, computes industrial requirements to build weapons, and determines emergency investment demand.

[9] The Council of Economic Advisers, an agency established by Congress within the Executive Office of the President, was created to present objective advice on both domestic and international economic policy. The Council makes recommendations based on analysis of economic research and empirical data.

and convert it from final demand to total requirements demand (this conversion is done by a special post-processor utility program that operates between ILIAD and FORCEMOB).[10]

A run of FORCEMOB is then made using that total requirements demand (correctly formatted for FORCEMOB), with the inputs to FORCEMOB set to model:

- No homeland damage
- No exclusion of non-essential civilian demand (i.e., no civilian austerity)
- No extraordinary military (conflict military) weapon requirements for regeneration
- No adjustments to imports or exports
- No emergency investment

In fact, after the output of the economic models has been converted from final demand to total requirements demand, the only role for FORCEMOB itself is to generate output that is in the correct format to be read by the material demand computation programs. The portions of FORCEMOB that deal with adjustment factors, weapon regeneration requirements, and emergency investment do not operate.

The FORCEMOB output is then run through the material demand computation programs[11] to produce peacetime material demands, by material, year, and category (defense or civilian; emergency investment demand is not relevant in a peacetime scenario). The peacetime demands are used in the PEAP, as described in Section F. But first, peacetime material production estimates for the starting year of the Base Case scenario (or other scenario of interest) are computed.

E. Starting Estimated Production Methodology (SEP)

1. Background

Material production *capacity* is a fairly stable quantity.[12] Subject matter experts, such as the material commodity specialists at the U.S. Geological Survey (USGS), know the location of mines and other material production facilities (both U.S. and foreign) and the maximum amount of material they are able to produce. This information, along with knowledge of the facilities that

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[10] Total requirements demand includes industrial output that is used by other industries to manufacture their products. Final demand only includes industrial output that goes to end-users. See Miller and Blair (1985, 2009) for more explanation of these concepts.

[11] Description of these programs can be found in IDA Document D-5477 (Schwartz, 2015).

[12] But capacity can expand, although perhaps slowly, to accommodate increasing demand for materials. As noted earlier, the data development process has tended *not* to take such expansion into account.

are expected to come online in the scenario period, makes forecasting of material production capacity a fairly straightforward activity.

In contrast, the actual amount of material produced is very sensitive to economic factors, and attempts to forecast it are not made in the same manner as the economic models forecast the demands for goods and services (RAMF-SM Substep 2a). But as a starting point for the computation of inputs for the Base Case, rough estimates of the peacetime production of materials in the first scenario year (which in general occurs some years into the future) are made. These are estimates of the production in that year if the Base Case scenario were not to occur. The basic methodology for computing these estimates is described in Section 2, below. A number of data values are missing, and some judgments must be made about how to generate certain estimates. Some general principles underlying these judgments are discussed in Section 3.

2. The Basic Methodology

The SEP algorithm involves computing a production-to-capacity ratio for a recent year or years for each producing country (U.S. and foreign), and then applying this ratio to the capacity estimated for the first scenario year.[13]

Among the information the subject matter experts (generally from USGS) provide is:

1. Actual historical production amounts for several recent years (given in mass units, such as tons)
2. Historical production capacities for those years
3. Forecast production capacities, year by year through the end of the scenario period[14]

Data, where available, are provided for each combination of material and producing country.

Dividing the total production over the span of recent years by the total capacity over those years yields a production-to-capacity ratio. This ratio is assumed to remain constant over the near term, at least until the first year of the scenario. Therefore, an estimate of the production in the first scenario year can be made by multiplying the production-to-capacity ratio (estimated from historical data) by the capacity given for the first scenario year (a relatively straightforward forecast). This calculation is consistent with an assumption that a country will be operating at the same capacity percentage in the first scenario year as it is in the historical period. A separate

[13] For the 2015 Requirements Report study, the U.S. Geological Survey commodity specialists were asked to estimate production *capacity* for each year in the span 2011 through 2020, but were asked to give production amounts only for 2011 and 2012 (historical data) and not to estimate future production.

[14] This includes capacity from current facilities that are expected to still be in operation during the scenario period and planned future capacity that has a high expectation of being operational in the scenario period. Possible future capacity with less of a chance of becoming operational in the scenario period was identified and noted, but is not counted in the capacity total.

computation is made for each combination of material and producing country, including the United States, where applicable.

3. Dealing with Missing Data

Unfortunately, a considerable amount of data is missing—more so for the production than the capacity data. Many of the production values are marked "N/A" (not available). But some kind of initial estimate of peacetime production in the first scenario year, however rough, is needed for the next step of the supply adjustment procedure (PEAP). This section discusses some guidelines that were followed for generating these estimates in the 2015 Requirements Report study.

Supply *capacity* values are usually given, but sometimes are marked N/A. Such cases are generally dealt with by using the corresponding production value, if available.

For some countries, production amounts are not available. This is a case of missing data, and the procedure for dealing with it depends upon other relevant quantities. The major guidelines used are:

- If the country is listed as having some capacity in current years but is not listed as a current producer, this is indicative of idle capacity. With no reason to assume that production would resume before the start of the scenario, the production-to-capacity ratio is set to zero.
- If the country is listed as having some capacity in current years but the current production is listed as N/A (i.e., some production is taking place, but the subject matter expert doesn't know the amount), use the average production-to-capacity ratio of the countries where both production and capacity amounts are given.
- If the country is not listed as a current producer, and its current capacity is zero but its capacity in the first scenario year is nonzero, this is indicative of future capacity expected to come online. Estimate the production-to-capacity ratio as the average production-to-capacity ratio of the countries where both production and capacity amounts are given.

F. Peacetime Equilibrium Adjustment Process (PEAP)

Given the starting estimated production levels for the first scenario year, as computed by the SEP methodology, the next step is to adjust them so that supply will be equal to demand at the start of the Base Case scenario. The methodology involved is known as the Peacetime Equilibrium Adjustment Process (PEAP). Note that the SEP process did not consider material demands; PEAP does.

The guiding principle of PEAP is the "equilibrium property" that demand equals supply. More specifically, PEAP determines supply values and a "clearing" market share such that the

U.S. peacetime demand in the first year of the scenario will be exactly satisfied by the U.S. estimated production, plus the clearing share proportion of the foreign estimated production.

The PEAP procedure is performed separately for each material; the description below applies to one material. For precision in exposition, the description is presented in mathematical terms.

1. Inputs and Outputs

a. Inputs

SEP_{US} = U.S. starting estimated production level in the first scenario year

SEP_c = starting estimated production level for foreign country c in the first scenario year

SEP_{FT} = total foreign starting estimated production in the first scenario year (= total of SEP_c over all foreign countries)

PcD = U.S. demand (civilian plus military) in a peacetime case in the first scenario year (computed by the Peacetime Demand Method [PcDM])

b. Outputs

$P'EP_{US}$ = U.S. estimated production level in the first scenario year after the PEAP adjustments

$P'EP_c$ = estimated production level for foreign country c in the first scenario year after the PEAP adjustments

$P'EP_{FT}$ = total foreign estimated production in the first scenario year after the PEAP adjustments (= total of $P'EP_c$ over all foreign countries)

P'CMS = clearing market share value

PEAP is structured so that the outputs will have the equilibrium property:

$$PcD = P'EP_{US} + (P'CMS \times P'EP_{FT}).$$

That is, the U.S. peacetime demand in the first year of the scenario will be exactly satisfied by the U.S. estimated production, plus the clearing share proportion of the foreign estimated production.[15]

The outputs of PEAP then undergo further adjustments. The estimated production values go into the Ramp-up Process (RUP) and the clearing shares go into the Maximum Market Share

[15] This latter term—the clearing share proportion of the foreign estimated production—could be regarded as the imports in the first scenario year under peacetime conditions. An alternative approach to supply adjustment might involve forecasting the amount of material that would be imported in the first scenario year under peacetime conditions.

Method (MaxMSM), as discussed in subsequent sections of this paper. The outputs of RUP and MaxMSM go into the Stockpile Sizing Module itself.

2. Specific Steps of the PEAP Algorithm

Step 1) Start with the inputs as listed above.

Step 2) Compare the peacetime demand PcD with the U.S. estimated production SEP_{US} .

- If PcD $\leq SEP_{US}$, this means that U.S. estimated production is sufficient to satisfy the demand, without any foreign supply at all, and can be lowered so that it precisely meets the demand.[16] Set $P'EP_{US}$ = PcD, set $P'EP_c = SEP_c$ for each country c, set $P'EP_{FT} = SEP_{FT}$, and set P'CMS = 0. (This adjustment reduces artificial surpluses.) Go to Step 6.
- If PcD > SEP_{US}, U.S. estimated production is insufficient to satisfy the demand. Therefore, some foreign supply is needed. Set $P'EP_{US} = SEP_{US}$, set $P'EP_c = SEP_c$ for each country c, set $P'EP_{FT} = SEP_{FT}$, and set P'CMS so that share P'CMS of the foreign production will exactly equal the demand unsatisfied by U.S. production. That is, set P'CMS = (PcD – SEP_{US}) / SEP_{FT}. Go to Step 3.

Step 3) If P'CMS is not too large (the rule of thumb here is less than or equal to 0.75), the output values are deemed to be reasonable. Go to Step 6. Otherwise, go to Step 4.

Step 4) A large value of P'CMS (greater than 0.75) might indicate an error in the data. If the data have already been rechecked, go to Step 5.[17] Otherwise, recheck the data, re-estimate SEP_{US}, the SEP_c, and SEP_{FT} as necessary, and go to Step 2.

Step 5) If this step is reached, this means that P'CMS, as currently computed, is greater than 0.75. In this case, adjust the initial estimated production values upward toward capacity, proportionately across all producer countries (including the United States) so that a share value of 75% clears the market. That is, P'CMS is set to 0.75 and $P'EP_{US}$ and the $P'EP_c$ are set so that

$$PcD = P'EP_{US} + 0.75 \times P'EP_{FT},$$

where $P'EP_{FT}$ is the sum of the $P'EP_c$ over all producing foreign countries c. (This adjustment reduces the chance of artificial shortfalls.) Go to Step 6.

[16] This situation indicates the case in which the United States is a net exporter of the material.

[17] Rechecking the data might verify that the United States indeed imports a huge proportion of foreign production. In such a case, a large clearing share is reasonable, and the limit of 0.75 need not be imposed. The step listing presented in this section assumes that this is not the case.

Step 6) The final outputs of PEAP have now been computed. As noted previously, they satisfy the equilibrium condition

$$PcD = P'EP_{US} + (P'CMS \times P'EP_{FT}).$$

The effect of this is that no peacetime shortfalls or surpluses will occur at the start of the Base Case scenario period.

3. Flowchart of PEAP

A flowchart of PEAP appears in Figure 1.

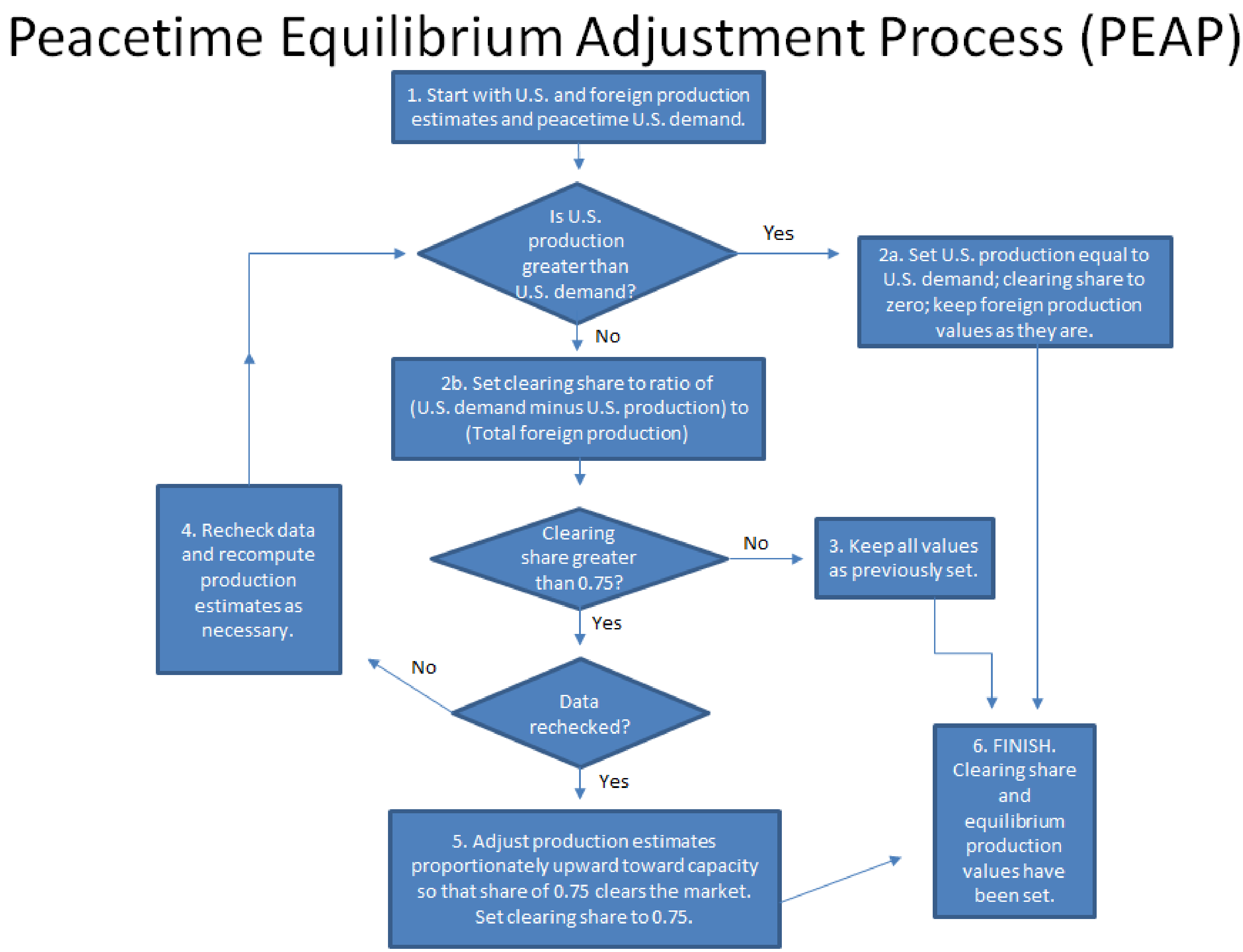

Figure 1. Flowchart of PEAP

G. The Maximum Market Share Method (MaxMSM)

In the context of RAMF-SM, the term “market share” refers to the proportion of *foreign* production that the United States can obtain in any given scenario. (All domestic production is assumed to be available.) The SSM allows the market share to vary by material and year of the scenario, but not by country. The data preparation process considers three different possible ways or measures of computing market share. The largest reasonable value of the three is used in the subsequent computations. The rationale for using the largest is that in a national emergency, the United States could use its economic power to obtain a larger share of foreign production than it obtains in peacetime. First, a provisional market share is computed based on peacetime data. This section describes the process. Afterwards, the market share is adjusted to take some of the national emergency scenario conditions into account, as discussed in Section H. The resultant value is input to the SSM. The process is performed separately for each material.

The three possible ways considered for computing market share are:

- Initial peacetime clearing share (P’CMS), computed by the Peacetime Equilibrium Adjustment Process , as described in Section F
- The imports ratio, i.e., the ratio of imports to non-U.S. production[18]
- Gross Domestic Product (GDP) ratio, i.e., the ratio of the U.S. GDP to the sum of the GDPs of all the countries that consume the material

Each of these measures has rationales:

Initial peacetime clearing share. A high value of P’CMS, i.e., a high peacetime market clearing at a time near the beginning of the Base Case implies that the United States needs—and gets—a rather large percentage of foreign supply. Reason exists to believe that the United States would continue to have this percentage during the scenario period (the SSM makes additional adjustments for supplier country reliability).

Imports ratio. Similarly, if the United States is already importing a large portion of foreign production, it is reasonable to believe this would continue in the scenario period (subject to additional adjustments for supplier country reliability).

GDP ratio. If the clearing share and the imports to non-U.S. production ratio are relatively low, reason still exists to believe that in a national emergency, the United States could use its economic clout—of which GDP is a measure—to obtain a larger share of

[18] It is possible to regard the initial peacetime clearing share as a ratio of estimated imports to estimated foreign production. In the context of this paper, the difference between the two measures is that the initial peacetime clearing share is based on projections of supply and demand in the first scenario year, while the imports ratio is based on recent historical data for imports and foreign production.

foreign production than it would in peacetime. As the U.S. GDP is growing more slowly than is the GDP in several other countries, that relative clout might be less in the scenario period, which is several years into the future, than it is now. A separate GDP ratio can be computed for each scenario year, using the projected GDPs for that year.[19]

Some data quality issues should be considered. Lists of countries consuming each material are furnished by subject matter experts. An incomplete list can make the GDP ratio artificially high; conversely, a long list of countries that consume small amounts of the material can make the ratio unrealistically low. The non-U.S. production data used in the construction of the imports ratio are sometimes incomplete; totaling them yields a low estimate of non-U.S. production and an artificially high imports ratio. Sometimes, the imports data have consistency problems. Judgment must be used when computing and evaluating the different measures, and when selecting the one to be used as the maximum market share.

H. Conflict-Related Adjustments to Maximum Market Share

A country that has suffered damage as a result of the conflict might well be less able to demand materials on the world market. This is modeled by decrementing its GDP by a war damage factor. Separate war damage factors for each combination of country and scenario year are provided as part of the conflict scenario specification. (The GDPs of countries not directly affected by the conflict are not decremented.) The modified GDP ratio for a given year uses the decremented non-U.S. GDP values for that year (both the peacetime GDP and the war damage factor can vary by year). If some of the demander countries suffer war damage, the modified GDP ratio will be greater than the peacetime one, because the denominator will be lower. (War damage to the United States is not explicitly modeled at this stage of the computations. Homeland damage increases U.S. demands for goods and services for repair purposes, but is not modeled as affecting its ability to bid for materials on world markets.)

If the GDP ratio is the largest of the three potential market share measures, then the modified GDP ratio is used as the market share in the Base Case. If one of the other potential measures is largest, war damage to demander countries still needs to be accounted for. This is done by multiplying the peacetime value of the selected measure by the factor by which the GDP ratio has been modified. For example, if the imports ratio is the largest potential market share measure, a modified imports ratio would be computed as follows:

[19] As the GDP ratio might be different for every scenario year, it is theoretically possible that it could be the biggest of the three measures in some years but not others. This has not happened with the actual data.

$$\text{imports ratio}^{\text{modified}} = \text{imports ratio}^{\text{peacetime}} \times (\text{GDP ratio}^{\text{modified}})/(\text{GDP ratio}^{\text{peacetime}})$$

A separate adjustment is performed separately for each scenario year. The series (over years) of modified imports ratios would then be used for the Base Case market share. If the largest peacetime ratio is P'CMS, the PEAP clearing share, the adjustment procedure is similar.

I. Ramp-up Process (RUP)

In NDS Requirements Report studies through 2005, the total U.S. and foreign capacity was all assumed to be immediately available, as soon as the national emergency scenario began. Foreign supply was subject to conflict-related decrements and delays, and the United States could only get a certain market share of it, but the full foreign capacity was used as the starting point for the application of these reduction factors. And the United States could use the full capacity of its domestic producers.

But this is unrealistic. At the point the Base Case scenario begins, some years in the future, material producers, both U.S. and foreign, will probably not be producing at full capacity. Rather, they will most likely be producing at a level that satisfies expected material demand at that time under peacetime, steady-state conditions. Even if the national emergency prompts the United States to induce material suppliers to produce at capacity, it will take some time for them to achieve a full-capacity level of production. For example, time would be needed to hire additional personnel and to ensure that currently unused machinery and other equipment are functioning properly.[20]

It is therefore desirable to have some kind of estimate of the (pre-decrement) material supply, U.S. and foreign, that would be available to the United States in the early part of the national emergency scenario.[21] This would be somewhere in between estimated peacetime production and full capacity. The methodology used is to postulate a length of time necessary for ramp-up to full capacity. The modeling allows different ramp-up times for U.S. and foreign supply, and even allows different ramp-up times for different foreign

[20] These kinds of assumptions are applicable to a scenario that begins suddenly with an intense conflict and then is followed by a regeneration period. This is the kind of scenario that for many years has been mandated for the Requirements Report. In a scenario that involved a lengthy pre-conflict mobilization period, it might be appropriate to model full capacity as being available, at least at the start of the conflict.

[21] The national emergency posited in the Base Case postulates that all necessary funding will be made available by the U.S. Government to achieve these computed levels of production: full capacity in the subsequent years and the intermediate-level production in the first year. This is assumed to apply to both U.S. and foreign production.

countries. In the 2015 Base Case, however, the ramp-up time is six months for all countries, U.S. and foreign.

Figure 2 illustrates how (pre-decrement) supply in the first year of the emergency scenario is calculated under a six-month ramp-up period. Suppose that a particular country is estimated to be producing a given material at a rate of 30 tons per year (at the start of the scenario), but has the capacity to produce 100 tons per year. The initial production rate comes from the SEP calculation, possibly modified by the PEAP process, as discussed in Sections E and F. The capacity value comes from USGS or a similar source. This rate function is consistent with a situation in which preparations have been taking place all during the ramp-up period; such preparations do not lead to increased production during the ramp-up period itself, but enable full-capacity production immediately thereafter. The total amount produced in the first year is the area under this step function curve, which is mathematically equivalent to the average of the initial production rate and the capacity, or (30+100)/2, i.e., 65 tons. The first year supply (for the given country-material combination) is thus set to 65 tons. In subsequent years, production is assumed to be at full capacity and the supply amount is 100 tons in each year.

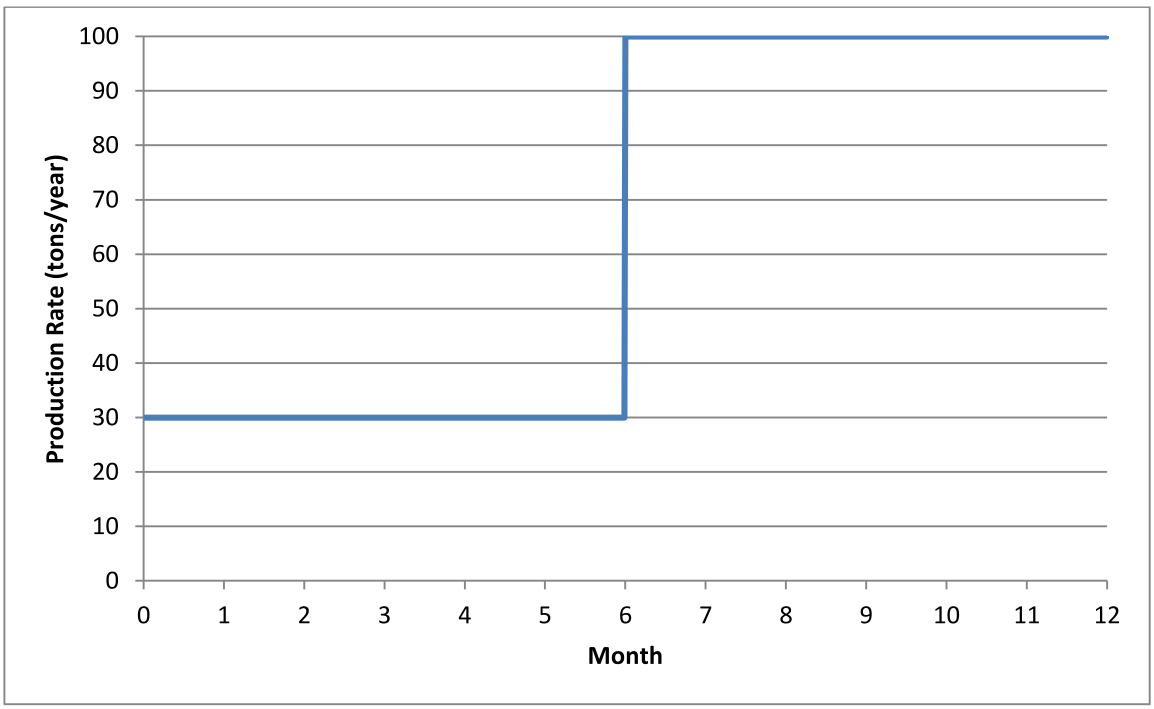

Figure 2. Production Under Six-Month Step Function Ramp-Up

It is worth noting that the term “ramp-up” has the connotation of a continuous buildup. Figure 3 illustrates that kind of situation, in which production starts at the peacetime rate and continuously increases to the capacity rate over the period of a year. The first year supply under this kind of continuous buildup would be the area under the curve in Figure 3. This area is also 65 tons, the same as the area under the curve in Figure 2. That is, the first year supply under a 12-month continuous ramp-up is the same as the first year supply under a six-month step function ramp-up. By convention, the ramp-up time has been associated with the supply amount generated by a step function ramp-up, but it could have been defined the other way.

Figure 3. Production Under 12-Month Continuous Ramp-Up

Using the step function construct, a ramp-up time of 12 months would be equivalent to setting the first year supply equal to the estimated production. A ramp-up time of zero corresponds to having full capacity in the first year. Ramp-up times of three months and nine months are clearly defined intermediate cases. Ramp-up times longer than 12 months would affect subsequent-year supply as well as first year supply, but have not been explored in the sensitivity cases performed to date.

As noted, a separate ramp-up computation is performed for each combination of material and producing country, resulting in first year supply values for each combination. These values, along with the capacity values for subsequent years, are written to the U.S. and foreign supply files that are input to the SSM.

J. Summary and Conclusions

An essential step in planning for the National Defense Stockpile involves the computation of material shortfalls under a national emergency scenario, which is posited to occur some years in the future. The determination of material shortfalls is modeled by estimating material demands and available material supplies under the conditions of the national emergency, and comparing the demand with the supply. The shortfall amounts clearly depend upon the predicted material demand and supply values. Acknowledging the imprecision of all forecasts, one still wants to make these predictions as accurate as possible, and to take into account all factors that might affect them.

One such factor is the economic equilibrium principle that under peacetime conditions, up until the national emergency starts, the material supply used by the U.S. will be more or less equal to U.S. material demand. The raw data on material demand and supply are not guaranteed to be in accord with this principle, in part, because the demand data and supply data are generated by separate sources using different methodologies. The material supply adjustment procedure provides a method for reconciling these data sets and generating adjusted supply values that take the equilibrium principle into account. Applying the procedure can reduce the possibility of “artificial” material shortfalls and surpluses that are mere artifacts of the data development process. This means the shortfalls that the modeling process computes are more likely to represent the actual effect of disturbances in supply and demand due to the national emergency. Such shortfalls, consequently, provide a more realistic basis for National Defense Stockpile planning.

Appendix A
Illustrations

Figures

Appendix B
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Appendix C
Abbreviations

DLA	Defense Logistics Agency
DOD	Department of Defense
FORCEMOB	Forces Mobilization Model
GDP	Gross Domestic Product
IDA	Institute for Defense Analyses
ILIAD	Inter-industry Large-scale Integrated and Dynamic model
INFORUM	Inter-industry Forecasting Project at the University of Maryland
LIFT	Long-term Inter-industry Forecasting Tool
MaxMSM	Maximum Market Share Method
NDS	National Defense Stockpile
P'CMS	Peacetime Clearing Market Share
PcDM	Peacetime Demand Method
PEAP	Peacetime Equilibrium Adjustment Process
RAMF-SM	Risk Assessment and Mitigation Framework for Strategic Materials
RUP	Ramp-up Process
SEP	Starting Estimated Production
SSM	Stockpile Sizing Module
USGS	U.S. Geological Survey

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